

FRDA REPORT 051

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DOUGLAS-FIR SEEDLINGS: TIMING OF
FUNGICIDE APPLICATION RELATED TO
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ABSTRACT.

The efficacy of three fungicides currently registered in British Columbia for control of grey mould on container-grown Douglas-fir seedlings were examined in a postinfective or curative spray program. Temperature and relative humidity previously identified to be optimum for the germination and infection by conidia of *Botrytis cinerea* on horticultural crops were used to schedule fungicide application. End of season grey mould severity on treated seedlings was compared to seedlings sprayed with fungicides on a routine basis. Post infective sprays of captan (Captan), chlorothalonil (Bravo 500) and benomyl (Benlate) were no less effective than those timed to the production spray schedule. Of all the postinfective fungicide applications, those applied 48 h after an infection period were not as effective as those used within 24 and 36 h. The best disease control in the postinfective regime was obtained using Captan and Bravo 500. An effective dew duration sensor for use in the conifer seedling greenhouse is a prerequisite to more accurate prediction of grey mould infection periods prior to the implementation of an effective curative spray program.

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INTRODUCTION.

Grey mould caused by the fungus *Botrytis cinerea* (Fr.: Nocca & Balbis), is a major impediment to the production of container-grown conifer seedlings in British Columbia (Sutherland and Van Eerden 1980). In the nursery, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is particularly susceptible to the disease (Sutherland et al. 1981). Diseased seedlings may either be killed outright or develop an overall lack of vigour which reduces their survival after outplanting. Grey mould losses encountered during lifting of seedlings often reaches 25-30%. These losses may become higher if *B. cinerea* is carried over to affect cold-stored seedlings.

Grey mould management in container nurseries currently relies heavily on protectant fungicide sprays of benomyl, chlorothalonil or captan. These are usually applied prior to seedling canopy closure (*sensu* Ford-Robertson 1971), then throughout the remainder of the growing season and again immediately prior to seedling storage. Full-season protectant programs of more than five spray applications are increasingly resulting in yield-loss while still promoting strains of *B. cinerea* that show tolerance to fungicides (Glover 1985).

An alternative to a protectant fungicide program is a postinfective or curative one in which fungicide is applied after conditions have been suitable for infection, but prior to symptom development. Disease control as good as or better than that achieved using fixed schedule protection regimes has been observed on a variety of horticultural crops using environmentally scheduled curative sprays (MacKenzie 1981; Dainello and Jones 1984; Ellis et al. 1986). Spray schedules are based upon the presence of optimum

environmental conditions in the vicinity of a susceptible host coinciding with inoculum levels sufficient for infection. Fungicide is applied sometime after the occurrence of such a period but, prior to symptom development.

Grey mould symptoms on container-grown Douglas-fir seedlings usually become evident in late August or early September. However, airborne *B. cinerea* conidia in sufficient numbers to initiate a grey mould epidemic (Bullit et al. 1970) have been observed in container greenhouses 6-8 weeks earlier than this (Peterson 1986). Douglas-fir seedlings are thought to be susceptible to infection at this time and following canopy closure (late-June to mid-July) Peterson (1986) observed temperatures of 15-20°C combined with relative humidities (RH) of at least 98% in the seedling canopy. These conditions are optimum for spore germination and infection by conidia of *B. cinerea* on a variety of horticultural crops (Nelson 1951; Jarvis 1962; Bullit et al. 1970; Trolinger 1983). As a corollary, with a susceptible host and sufficient numbers of spores present to initiate an epidemic, the occurrence of favourable environmental conditions may determine the success or failure of grey mould infection on container-grown Douglas-fir seedlings. Because *B. cinerea* can exist in a latent or quiescent phase prior to the development of aggressive pathogenicity (Jarvis 1962, 1977), infection of seedlings could be occurring 4-6 weeks prior to the presence of visual symptoms.

A predictive model for grey mould infection on container-grown conifer seedlings utilizing leaf (needle) wetness duration and temperature has not yet been developed. Electrical-resistance leaf wetness sensors in conifer greenhouses produce highly variable readings (Peterson 1986). This likely results from nutrients being

applied with the overhead irrigation causing rapid electrolyte buildup on the sensors and alteration of their surface resistance. However, it was felt that accurate scheduling of fungicide sprays to closely coincide with grey mould infection periods identified for horticultural crops could benefit disease management on container-grown Douglas-fir. Thus, three fungicides currently used in grey mould protectant programs were evaluated for effectiveness in a postinfective regime with their application scheduled using temperature and RH parameters previously found optimum for infection on horticultural crops.

MATERIALS AND METHODS.

The experiment was conducted in a polyethylene-covered greenhouse of 500 m² operated by Canadian International Paper Inc. (CIP) at Saanichton, British Columbia. Douglas-fir seedlings, from a single, mid-elevation seedlot (seedlot # 9558) sown in April 1987, were grown using standard nursery production procedures (Matthews 1981). Seedlings were grown in PSB313 160 styroblock containers on benches 1 m above an asphalt floor. Each styroblock has 160 cavities resulting in a density of 764 seedlings/m². Water and nutrients were supplied to the trees by an overhead irrigation boom.

To verify the presence of airborne *B. cinerea* conidia in sufficient numbers for a grey mould epidemic to start, a 24 h volumetric spore trap (FTS Spore Recording Trap, Victoria, B.C.) similar to that described by Gadoury and MacHardy (1983) was operated in the greenhouse from June through to October. Tape was extracted from the trap daily, dissected into six, 4 h segments (00:00-04:00, 04:00-08:00, 08:00-12:00, 12:00-16:00, 16:00-20:00, 20:00-24:00), and examined microscopically. *Botrytis cinerea* spores were identified by distinct morphological characteristics and after counting, estimates of their atmospheric density during each 4 h time period were made.

Microclimatic conditions within the seedling canopy were recorded from 1 June to 30 November, 1987 using sensors connected to a microprocessor-based datalogger (Campbell Scientific 21X, Edmonton, Alberta). Canopy RH was calculated from wet and dry bulb temperatures obtained using copper-constantan thermocouples configured in an aspirated psychrometer placed in the seedling canopy 0.03 m above the styroblock surface. The thermocouple

psychrometer was initially calibrated to an Assman psychrometer and measurements periodically verified throughout the experiment. Canopy temperature was taken from the dry bulb thermocouple. Observations of temperature and RH were made every 0.5 h following a 2 min. period of aspiration. Data were extracted each day and examined for the occurrence of an infection period (temperature 15-20°C with RH at least 98%) of 3 h duration or longer. Following detection of such a period, fungicide sprays were applied accordingly.

When applied in response to the presence of environmental conditions favouring infection, the efficacy of three fungicides for curative control of grey mould on Douglas-fir seedlings was examined. Benomyl (Benlate 50W), chlorothalonil (Bravo 500 F) and captan (Captan 50WP) were applied at product rates of 11.2 g/100 m², 32 mL/100 m² and 22.4 g/100 m² respectively as per the British Columbia Ministry of Agriculture and Food (1987) Nursery Production Guide for Commercial Growers. Fungicides in the above dosages were mixed with a tap water carrier that was applied at a rate of 33 L/100 m² from a 5 L hand sprayer. An application pressure of 300 KPa was maintained until the sprayer was exhausted. Control seedlings were sprayed with tap water. Each fungicide and a control was applied within 24 h, 36 h and 48 h following the occurrence of an infection period. A final treatment consisted of standard production sprays applied at CIP's fixed schedule production spray interval. The total number of experimental treatments equaled 13 as follows: one four level spray factor (benomyl, chlorothalonil, captan, control), one three level time factor (24 h, 36 h, 48 h) and a one level production spray factor.

One treatment replicate consisted of a PSB313 160 styroblock containing 160 seedlings. Each treatment was replicated 10 times

for a total of 130 styroblocks. To facilitate fungicide application and infection period identification, styroblocks for each level of the time factor were grouped together on the growing benches. Treatments within each time level were randomized within the interval group. To avoid contamination between fungicides, the 10 replicate styroblocks of each level of the spray factor were removed from a time interval group and sprayed some distance away from the others. The styroblocks were then returned to the bench.

Periods longer than 3 h duration with temperature 15-20°C and RH at least 98% were observed and treatment sprays applied within 24, 36, and 48 h of their occurrence on 27 June, 15 July, 29 July, 22 August and 7 September. All treatments were applied within 1 h of the desired time period. The manufacturer's suggested activity period for each fungicide lasted a minimum of 10 days. Thus, infection periods occurring within 10 days following fungicide application were disregarded. After 10 days, treatments were applied in response to the occurrence of the next infection period. One CIP production spray of chlorothalonil was applied at a rate of 32 mL in 33 L of water/100 m² on 17 July and a combined captan-chlorothalonil spray was applied at a rate of captan (22.4 g) and chlorothalonil (11.2 g) both mixed in 33 L of water/100 m² on 18 November.

Efficacy and severity ratings were begun on 28 December and made for each styroblock using two rating systems. A fungicide efficacy rating was obtained by estimating the percentage of seedlings/styroblock affected by grey mould as follows:

Rating	Percentage seedlings affected
1	0 - 25%
2	26 - 50%
3	51 - 75%
4	76 - 100%

Disease severity in each styroblock was rated as follows:

Rating	Disease severity
1	very light (few bottom needles affected)
2	light (lower needles affected)
3	light-moderate (lower 25% seedling affected)
4	moderate (lower 33% seedling affected)
5	moderate-severe (lower 66% seedling affected)
6	severe (entire seedling affected or dead)

Activity of the pathogen (presence of conidia) was also noted.

Beginning on 4 January, 1988, five seedlings from each styroblock were sampled for morphological effects of the treatments. Height (from root collar to bud tip) and stem diameter (at root collar) was measured for each seedling. All data were analyzed on an IBM microcomputer using PC SAS. Efficacy and disease severity data were examined separately and then ratings of each were added to produce a composite value of spray efficacy and disease severity. All data were subjected to a chi-square test for normality prior to further analysis. The data were then ranked enabling examination, using analysis of variance on the ranked values, equivalent to a Kruskal Wallis nonparametric analysis of variance (Zar 1984). Tukey's studentized range test was also utilized on the ranked data to indicate significant differences between specific spray treatments. Seedling morphological characteristics of height and root collar diameter were normally distributed as indicated by

Chi-square tests. Thus, these data were not ranked and a two factor, parametric analysis of variance was performed on them. Also Tukey's studentized range test was used to indicate differences between treatments.

RESULTS.

Greenhouse environmental conditions favourable for grey mould infection on Douglas-fir seedlings were observed from June through to October. During these months, mean airborne spores of *B. cinerea* in six daily 4 h periods were observed in numbers greater than 40/m³ suggested by Bullt et al (1970) to be sufficient to start a grey mould epidemic (Fig. 1). Favourable environmental conditions for *B. cinerea* spore germination also occurred during these months in periods of sufficient duration for grey mould infection to have taken place (Table 1).

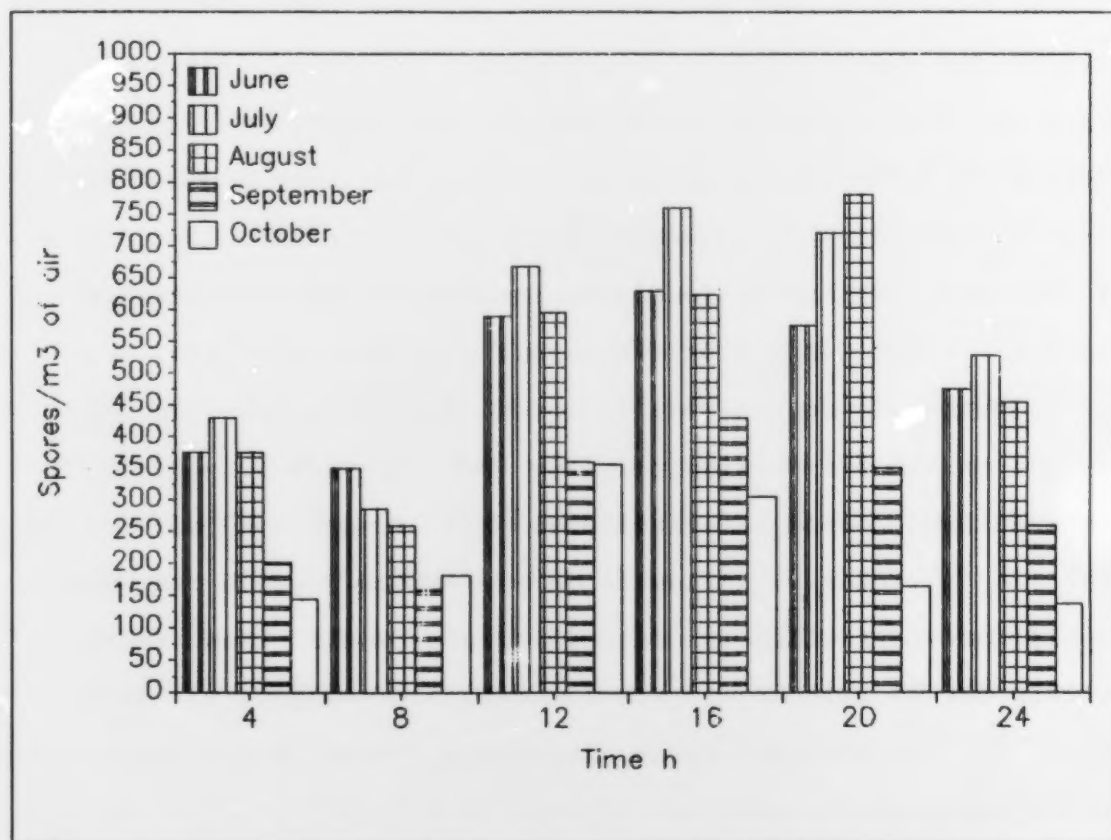


FIGURE 1. Mean diurnal airborne spore densities for six, 4 h time intervals inside the greenhouse during June, July, August and September.

TABLE 1. Days per month when temperature was 15-20°C and RH at least 98% for periods > 3 h and the mean hours per day those conditions prevailed.

Month	Number of days	Mean h/day
June	5	5.1
July	4	4.1
August	8	5.6
September	4	3.5
October	1	3.0

Following the application of postinfective fungicide sprays to control grey mould on container-grown Douglas-fir seedlings, a two factor Kruskal Wallis nonparametric analysis of variance showed no significant differences among fungicide efficacy ($P=0.05$, $H=2.98$, $df=3$) or between crosses of fungicide and time of application ($P=0.05$, $H=2.25$, $df=11$) (Zar 1984) (Appendix 1). However, efficacy of times of fungicide application following the detection of an infection period did differ significantly ($P=0.05$, $H=6.57$, $df=2$). Tukey's studentized range test indicated all fungicides applied during the 36 h interval following an infection period to be significantly more effective in controlling grey mould than those applied within the 48 h interval ($P=0.05$, $df=117$). The 24 h, 36 h and production scheduled spray intervals did not differ significantly among each other.

No significant difference in disease severity was indicated between fungicide levels by the ANOVA ($P=0.05$, $H=7.26$, $df=3$) (Appendix 2). Tukey's studentized range test did however show grey mould on Douglas-fir seedlings treated with captan and

chlorothalonil was significantly less severe than on those treated with benomyl ($P=0.05$, $df=117$). No significant differences in severity of disease was indicated between the control or production sprayed seedlings and any of the other levels of fungicide applied. No significant differences between grey mould severity were observed among the levels of time of fungicide application or between any crossed combinations of spray and time ($P=0.05$, $df=117$).

Analysis of variance performed on composite ranks of efficacy and severity ratings indicated no significant difference between fungicide used ($P=0.05$, $H=6.39$, $df=3$), times of application ($P=0.05$, $H=3.67$, $df=2$) and crossed combinations of fungicide and time ($P=0.05$, $H=2.75$, $df=11$) (Appendix 3). Tukey's studentized range test indicated captan and chlorothalonil treated seedlings to have composite efficacy and disease severity ratings ranked significantly lower than those treated with benomyl ($P=0.05$, $df=117$). No significant differences between composite ranks were indicated among any levels of application time. Tukey's studentized range test showed that composite ratings of fungicide efficacy and disease severity of seedlings that had benomyl applied 36 h after an infection period were ranked significantly higher than any other combination of spray and time ($P=0.05$, $df=117$). The same test indicated that composite ratings of seedlings that had captan applied 48 h after an infection period were ranked significantly lower than any other combination of spray and time.

Analysis of variance on seedling height measurements indicated no significant difference among seedling heights between fungicides used ($P=0.05$, $F=0.54$, $dfn=3$ $dfd=103$) (Appendix 4). Significant differences among seedling heights were indicated between levels of time of spray application ($P=0.05$, $F=30.08$, $dfn=2$ $dfd=103$) and

between crossed combinations of fungicide and time of application ($P=0.05$, $F=6.96$, $dfn=11$ $dfd=103$). Tukey's studentized range test indicated that seedlings treated 36 h after an infection period (mean height 0.281 m) were significantly taller than those treated with CIP's production spray timing (mean height 0.269 m) ($P=0.05$, $df=117$) and those treated within 48 h (mean height 0.265 m) ($P=0.05$, $df=117$). Seedlings treated within 24 h of an infection period (mean height 0.277 m) were significantly taller than those treated within 48 h (mean height 0.265 m) ($P=0.05$, $df=117$). Tukey's studentized range test on crossed combinations of fungicide and time of application showed a significant difference among seedling heights between, one group that received all levels of fungicide within 24 and 36 h of an infection period and another group that received all levels of fungicide within 48 h of an infection period and those that received CIP's production sprays ($P=0.05$, $df=117$).

Analysis of variance performed on root collar diameter measurements of the treated seedlings indicated no significant differences among seedlings treated with all levels of fungicide ($P=0.05$, $F=1.42$, $dfn=3$, $dfd=103$); times of application ($P=0.05$, $F=2.04$, $dfn=2$ $dfd=103$); and crossed combinations of fungicide and times of application ($P=0.05$, $F=1.21$, $dfn=11$ $dfd=103$) (Appendix 5). No significant differences in seedling root collar diameter were indicated among any of the treated seedlings using Tukey's studentized range test ($P=0.05$, $df=117$).

DISCUSSION.

Opportunities for the initiation and continuation of a grey mould epidemic on container-grown Douglas-fir seedlings occurred readily through the course of this study. The infection prerequisites of sufficient inoculum (Fig. 1) and a suitable host were present from 1 June onwards. Environmental conditions near the seedlings were such that germination and infection by conidia of *B. cinerea* would have been possible on a number of days from June through October (Table 1).

The results indicate time of application to be important with regard to fungicide efficacy. However, none of the postinfective spray times were more efficacious than those timed to the production spray schedule. The fact that the 24 h and 36 h spray treatments were no less efficacious than the fixed schedule sprays while the 48 h treatment was not as effective shows that timing of sprays around infection periods may affect future crop disease incidence. Fungicide applied to horticultural crops in the expectation of disease has shown a considerable measure of control (Maude 1980). The success of such an approach is related to the mode of action of the fungus. Powelson (1960) showed that strawberry fruits were not attacked primarily by *B. cinerea* but were secondarily invaded by the fungus, latent in flower parts that had been directly infected some time earlier. The pathogen presumably operates in this manner on Douglas-fir seedlings; i.e. latent infections in senescent needles, secondarily infect succulent healthy tissues as the season progresses. As a corollary, although no better control was obtained from the 24 h and 36 h timed sprays compared to the production spray, the postinfective sprays were no worse. The early 24 and

36 h sprays following infection likely kill sufficient conidia prior to the establishment of a latent infection to retard later secondary spread. Waiting 48 h after an infection period prior to applying fungicide likely provides sufficient time for primary latent infection development on senescent needles.

That grey mould on sprayed seedlings was most severe on those treated with benomyl concurs with findings of other research indicating isolates of *B. cinerea* to be tolerant to benomyl (Glover 1985). With primary grey mould infection on Douglas-fir seedlings occurring on senescent needles, it may not be affected by Benlate whose mode of action is systemic.

Phytotoxic effects of a postinfective spray program as reflected in the morphological characteristics of seedling height and root collar diameter were minimal. Small differences among seedling heights and no significant differences between root collar diameters indicate this. The statistical significance of differences among seedling heights was caused by small variation within the sample.

Prediction of grey mould infection periods requires accurate estimation of times with high RH and/or free water on leaf (needle) surfaces. The use of humidity data alone can be misleading at high RH's where small temperature changes can result in undetected dew formation. Prior to the development of an accurate curative spray program for grey mould on Douglas-fir seedlings, more precise measurement of leaf wetness duration is needed than our study provided. The research does indicate however, that with more accurate prediction of infection periods, control of grey mould in a postinfective spray program could be achieved. To reduce the chance of primary latent infection occurring, the contact fungicides captan

or chlorothalonil currently registered for use on container seedlings in British Columbia, would perform best in such a curative spray regime.

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APPENDIX 1.

Efficacy Ranks

Kruskal Wallis Nonparametric Analysis of Variance Procedure.

Dependent Variable:EFFICACY RANK. P=0.05

R-Square	C.V.	Root MSE
0.312	42.58	2.76

Source of Variation	df	ANOVA SS	Mean Square	H	Hcrit
Fungicide	3	68.55	22.85	2.98	7.815
Time of Application	2	100.66	50.33	6.57	5.991
Fungicide*Time	11	189.20	17.2	2.25	19.67

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: EFFICACY RANK.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'

Fungicide Comparison			Difference Between Means
Benomyl	-	control	0.183
Benomyl	-	chlorothalonil	1.050
Benomyl	-	production	1.050
Benomyl	-	captan	2.100
Control	-	chlorothalonil	0.867
Control	-	production	0.867
Control	-	captan	1.917
Chlorothalonil	-	production	0.000
Chlorothalonil	-	captan	1.050
Production	-	captan	1.050

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: EFFICACY RANK.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Time of Application Comparison			Difference Between Means	
24 h	-	36 h	-0.750	
24 h	-	48 h	1.675	
24 h	-	production	0.525	
36 h	-	48 h	2.425	***
36 h	-	production	1.275	
48 h	-	production	-1.150	

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: EFFICACY RANK.

P=0.05 df=117

Means with the same letter are not significantly different.

Cross of Fungicide*Time	Mean Rank	Tukey Grouping
Benomyl*36 h	9.6	A
Control*36 h	8.9	A
Benomyl*24 h	8.4	A
Chlorothalonil*36 h	7.8	A
Control*24 h	7.7	A
Chlorothalonil*24 h	6.9	A
Production	6.8	A
Control*48 h	6.5	A
Captan*24 h	6.4	A
Captan*36 h	6.1	A
Chlorothalonil*48 h	5.8	A
Benomyl*48 h	5.6	A
Captan*48 h	4.8	A

APPENDIX 2.

Severity Ranks.

Kruskal Wallis Nonparametric Analysis of Variance Procedure.

Dependent Variable: SEVERITY RANK.

P=0.05

R-Square

C.V.

Root MSE

0.335

43.59

2.83

Source of Variation	df	ANOVA SS	Mean Square	H	Hcrit
Fungicide	3	174.85	58.28	7.26	7.815
Time of Application	2	23.89	11.94	1.49	5.991
Fungicide*time	11	218.25	19.84	2.47	19.67

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: SEVERITY RANK.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Fungicide Comparison			Difference Between Means	
Benomyl	-	production	0.950	
Benomyl	-	control	1.383	
Benomyl	-	chlorothalonil	2.933	***
Benomyl	-	captan	3.383	***
Production	-	control	0.433	
Production	-	chlorothalonil	1.983	
Production	-	captan	2.433	
Control	-	chlorothalonil	1.550	
Control	-	captan	2.000	
Chlorothalonil	-	captan	0.450	

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: SEVERITY RANK.

$P=0.05$ $df=117$

Comparisons significant at $P=0.05$ are indicated by '***'.

Time of Application Comparison			Difference Between Means
Production	-	36 h	0.300
Production	-	48 h	1.250
Production	-	24 h	1.375
36 h	-	48 h	0.950
36 h	-	24 h	1.075
48 h	-	24 h	0.125

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: SEVERITY RANK.

P=0.05 df=117

Means with the same letter are not significantly different.

Cross of Fungicide*Time	Mean Rank	Tukey Grouping
Benomyl*36 h	9.9	A
Benomyl*48 h	8.8	A
Control*36 h	8.6	A
Benomyl*24 h	8.0	A
Production	7.9	A
Control*24 h	7.4	A
Chlorothalonil*36 h	6.7	A
Control*24 h	6.5	A
Captan*24 h	6.0	A
Chlorothalonil*24 h	5.7	A
Chlorothalonil*48 h	5.4	A
Captan*36 h	5.3	A
Captan*48 h	5.1	A

APPENDIX 3.

Composite Ranks.

Kruskal Wallis Nonparametric Analysis of Variance Procedure.

Dependent Variable: COMPOSIT RANK. P=0.05

R-Square	C.V.	Root MSE
0.36	44.76	2.91

Source of Variation	df	ANOVA SS	Mean Square	H	Hcrit
Fungicide	3	162.17	54.06	6.39	7.815
Time of Application	2	62.18	31.09	3.67	5.991
Fungicide*Time	11	255.75	23.25	2.75	19.67

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: COMPOSITE RANK.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Fungicide Comparison			Difference Between Means	
Benomyl	-	control	1.017	
Benomyl	-	production	1.283	
Benomyl	-	chlorothalonil	2.567	***
Benomyl	-	captan	3.283	***
Control	-	production	0.267	
Control	-	chlorothalonil	1.550	
Control	-	captan	2.267	
Production	-	chlorothalonil	1.283	
Production	-	captan	2.000	
Chlorothalonil	-	captan	0.717	

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: COMPOSITE RANK.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Time of Application Comparison			Difference Between Means
36 h	-	production	0.587
36 h	-	24 h	1.100
36 h	-	48 h	1.962
Production	-	24 h	0.513
Production	-	48 h	1.375
24 h	-	48 h	0.862

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: COMPOSITE RANK.

P=0.05 df=117

Means with the same letter are not significantly different.

Cross of Fungicide*Time	Mean Rank	Tukey Grouping
Benomyl*36 h	10.4	A
Control*36 h	9.1	A B
Benomyl*24 h	8.6	A B
Production	7.4	A B
Chlorothalonil*36 h	7.3	A B
Control*48 h	7.2	A B
Benomyl*48 h	7.1	A B
Control*24 h	6.8	A B
Captan*24 h	6.3	A B
Chlorothalonil*24 h	6.0	A B
Captan*36 h	5.3	A B
Chlorothalonil*48 h	5.2	A B
Captan*48 h	4.7	B

APPENDIX 4.

Seedling Height.

Analysis of Variance Procedure.

Dependent Variable: HEIGHT.

P=0.05

R-Square	C.V.	Root MSE	HEIGHT mean
0.573	3.741	1.03	27.45

Source of Variation	df	ANOVA SS	Mean Square	F	Fcrit
Fungicide	3	1.694	0.565	0.54	3.25
Time of Application	2	63.473	31.736	30.08	3.83
Fungicide*Time	11	80.794	7.345	6.96	2.12

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: HEIGHT.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Fungicide Comparison			Difference Between Means
Benomyl	-	control	0.263
Benomyl	-	captan	0.267
Benomyl	-	chlorothalonil	0.290
Benomyl	-	production	0.667
Control	-	captan	0.003
Control	-	chlorothalonil	0.027
Control	-	production	0.403
Captan	-	chlorothalonil	0.023
Captan	-	production	0.400
Chlorothalonil	-	production	0.377

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: HEIGHT.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '***'.

Time of Application Comparison			Difference Between Means	
36 h	-	24 h	0.440	
36 h	-	production	1.180	***
36 h	-	48 h	1.715	***
24 h	-	production	0.740	
24 h	-	48 h	1.275	***
Production	-	48 h	0.535	

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: HEIGHT.

P=0.05 df=117

Means with the same letter are not significantly different.

Cross of Fungicide*Time	Mean Height	Tukey Grouping		
Benomyl*36 h	28.93	A		
Captan*36 h	28.19	A	B	
Chlorothalonil*24 h	28.11	A	B	
Chlorothalonil*36 h	27.88	A	B	C
Captan*24 h	27.83	A	B	C
Control*24 h	27.75	A	B	C
Control*36 h	27.68	A	B	C
Benomyl*24 h	27.23	A	B	C
Production	26.99		B	C
Benomyl*48 h	26.81		B	C
Control*48 h	26.75		B	C
Captan*48 h	26.15			C
Chlorothalonil*48 h	26.11			C

APPENDIX 5.

Seedling Caliper.

Analysis of Variance Procedure.

Dependent Variable: CALIPER.

P=0.05

R-Square

C.V.

Root MSE

CALIPER mean

0.173

4.511

0.013

0.290

Source of
Variation

df

ANOVA SS

Mean Square

F

Fcrit

Fungicide

3

0.0007

0.0002

1.42

3.25

Time of
Application

2

0.0007

0.0003

2.04

3.83

Fungicide*Time

11

0.0022

0.0002

1.21

2.12

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: CALIPER.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '****'.

Fungicide Comparison			Difference Between Means
Captan	-	control	0.00413
Captan	-	benomyl	0.00560
Captan	-	production	0.00600
Captan	-	chlorothalonil	0.00640
Control	-	benomyl	0.00147
Control	-	production	0.00187
Control	-	chlorothalonil	0.00227
Benomyl	-	production	0.00040
Benomyl	-	chlorothalonil	0.00080
Production	-	chlorothalonil	0.00040

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: CALIPER.

P=0.05 df=117

Comparisons significant at P=0.05 are indicated by '****'.

Time of Application Comparison			Difference Between Means
36 h	-	24 h	0.00200
36 h	-	production	0.00457
36 h	-	48 h	0.00582
24 h	-	production	0.00257
24 h	-	48 h	0.00382
Production	-	48 h	0.00125

TUKEY'S STUDENTIZED RANGE TEST FOR VARIABLE: CALIPER.

P=0.05 df=117

Means with the same letter are not significantly different.

Cross of Fungicide*Time	Mean Caliper	Tukey Grouping
Captan*36 h	0.297	A
Captan*24 h	0.296	A
Benomyl*36 h	0.296	A
Control*24 h	0.294	A
Control*36 h	0.291	A
Chlorothalonil*24 h	0.290	A
Captan*48h	0.290	A
Production	0.288	A
Chlorothalonil*36 h	0.288	A
Benomyl*48 h	0.287	A
Control*48 h	0.286	A
Chlorothalonil*48 h	0.285	A
Benomyl*24 h	0.283	A